An Incremental Life-cycle Assurance Strategy for Critical System Certification

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Report Documentation Page

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Outline

- Challenges in Safety-critical Software-intensive systems
- An Architecture-centric Virtual Integration Strategy with SAE AADL
- Improving the Quality of Requirements
- Architecture Fault Modeling and Safety
- Incremental Life-cycle Assurance of Systems
- Summary and Conclusion

We Rely on Software for Safe Aircraft Operation

Even with the autopilot off, flight control computers still ``command control surfaces to protect the aircraft from unsafe conditions such as a stall,'' the investigators said.

The unit continued to send false stall and speed warnings to the aircraft's primary computer and about 2 minutes after the initial fault ``generated very high, random and incorrect values for the aircraft's angle of attack.''

Embedded software systems introduce a new class of problems not addressed by traditional system modeling & analysis

Quantas
Landing

Written by htbw

From: soyawan

mayday call when it suddenly changed altitude during a flight from Singapore to Perth, Qantas said.

lunge

wide

irways

causing the jet to nosedive.

was cruising at 37,000 feet (11,277 meters) when the computer fed incorrect information to the flight control system, the **Australian Transport Safety Bureau** said yesterday. The aircraft dropped 650 feet within seconds, slamming passengers and crew into the cabin ceiling, before the pilots regained control.

``This appears to be a unique event,'' the bureau said, adding that

fitted with the same air-data computer. The advisory is ``aimed at minimizing the risk in the unlikely event of a similar occurrence.''

Autopilot Off

A ``preliminary analysis'' of the Qantas plunge showed the error occurred in one of the jet's three air data inertial reference units, which caused the autopilot to disconnect, the ATSB said in a statement on its Web site.

The crew flew the aircraft manually to the end of the flight, except for a period of a few seconds, the bureau said.

Even with the autopilot off, flight control computers still ``command control surfaces to protect the aircraft from unsafe conditions such as a stall,'' the investigators said.

The unit continued to send false stall and speed warnings to the aircraft's primary computer and about 2 minutes after the initial fault ``generated very high, random and incorrect values for the aircraft's angle of attack.''

The flight control computer then commanded a ``nose-down aircraft movement, which resulted in the aircraft pitching down to a maximum of about 8.5 degrees,'' it said.

No `Similar Event'

``Airbus has advised that it is not aware of any similar event over the many years of operation of the Airbus,'' the bureau added, saying it will continue investigating.

Software Problems not just in Aircraft

May 7, 2010

Lexus GX 460 passes retest; Consumer Reports lifts "Don't Buy" label

Consumer Reports is lifting the Don't Buy: Safety Risk designation from the 2010 Lexus GX 460 SUV after recall work corrected the problem it displayed in one of our emergency handling tests. (See the original report and video: "Don't Buy: Safety Risk--2010 Lexus GX 460.")

We originally experienced the problem in a test that we use to evaluate what's called lift-off oversteer. In this test, as the vehicle is driven through a turn, the driver quickly lifts his foot off the accelerator pedal to see how the vehicle reacts. When we did this with our GX 460, its rear end slid out until the vehicle was almost sideways. Although the GX 460 has electronic stability control, which is designed to prevent a vehicle from sliding, the system wasn't intervening quickly enough to stop the slide. We consider this a safety risk because in a real-world situation this could cause a rear tire to strike a curb or slide off of the pavement, possibly causing the vehicle to roll over. Tall vehicles with a high center of gravity, such as the GX 460, heighten our concern. We are not aware, however, of any reports of injury related to this problem.

Lexus recently duplicated the problem on its own test track and developed a software upgrade for the vehicle's ESC system that would prevent the problem from happening. Dealers received the software fix last week and began notifying GX 460 owners to bring their vehicles in for repair.

We contacted the Lexus dealership from which we had anonymously bought the vehicle and made an appointment to have the recall work performed. The work took about an hour and a half.

Following that, we again put the SUV through our full series of emergency handling tests. This time, the ESC system intervened earlier and its rear did not slide out in the lift-off oversteer test. Instead, the vehicle understeered—or plowed—when it exceeded its limits of traction, which is a more common result and makes the vehicle more predictable and less likely to roll over. Overall, we did not experience any safety concerns with the corrected GX 460 in our handling tests.

Expert • Independent • Nonprofit

ConsumerReports.org

This article appeared in May 2010 Consumer Reports Magazine.

Many appliances now rely on electronic controls and operating softw... But it turned out to be a problem for the Kenmore 4027 front-loader, which scored near the bottom in our February 2010 report.

Our tests found that the rinse cycles on some models worked improperly, resulting in an unimpressive cleaning.

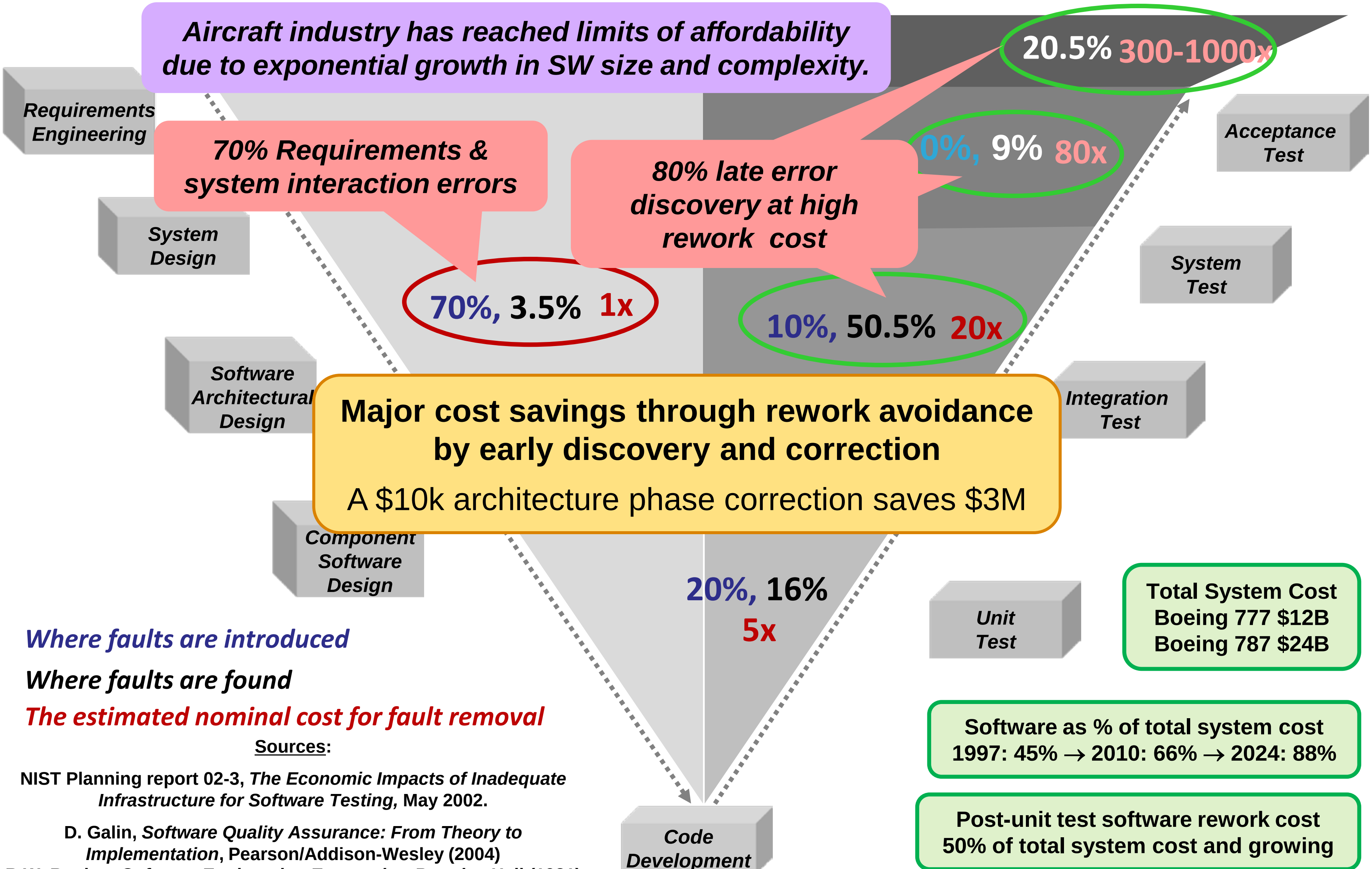
When Sears, which sells the washer, saw our February 2010 Ratings (available to subscribers), it worked with LG, which makes the washer, to figure out what was wrong. They quickly determined that a software problem was causing short or missing rinse and wash cycles, affecting wash performance. Sears and LG say they have reprogrammed the software on the models in their warehouses and on about 65 percent of the washers already sold, including the ones we had purchased.

Our retests of the reprogrammed Kenmore 4027 found that the cycles now worked properly, and the machine excelled. It now tops our Ratings (available to subscribers) of more than 50 front-loaders and we've made it a CR Best Buy.

If you own the washer, or a related model such as the Kenmore 4044 or Kenmore Elite 4051 or 4219, you should get a letter from Sears for a free service call. Or you can call 800-733-2299.

How do you upgrade washing machine software?

High Fault Leakage Drives Major Increase in Rework Cost



Where faults are introduced

Where faults are found

The estimated nominal cost for fault removal

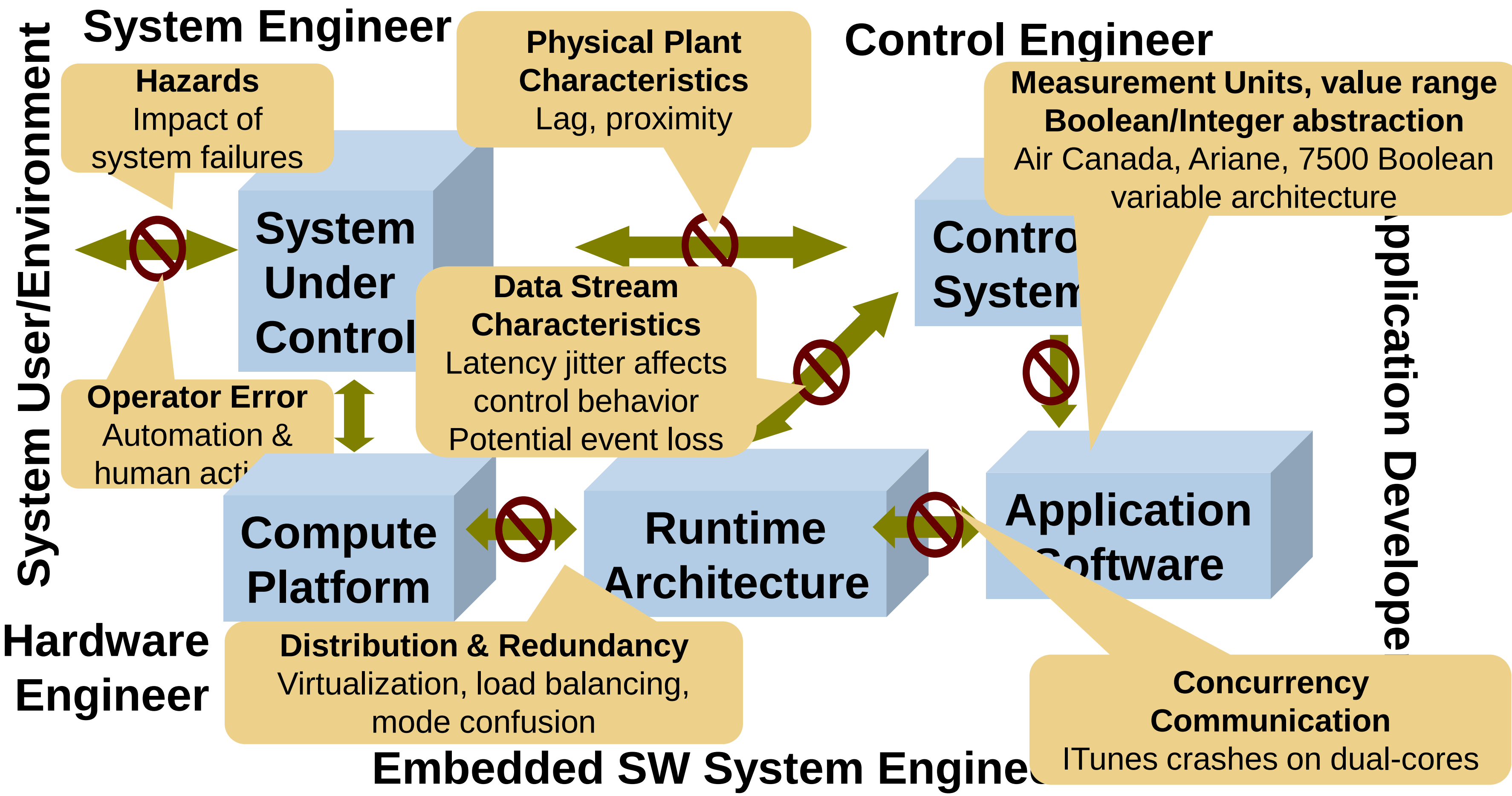
Sources:

NIST Planning report 02-3, *The Economic Impacts of Inadequate Infrastructure for Software Testing*, May 2002.

D. Galin, *Software Quality Assurance: From Theory to Implementation*, Pearson/Addison-Wesley (2004)

B.W. Boehm, *Software Engineering Economics*, Prentice Hall (1981)

Mismatched Assumptions in System Interactions



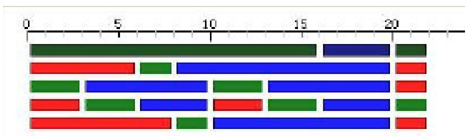
Embedded software system as major source of hazards

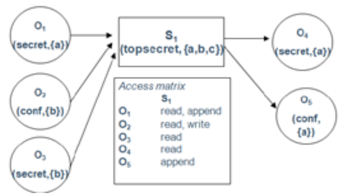
Why do system level failures still occur despite fault tolerance techniques being deployed in systems?

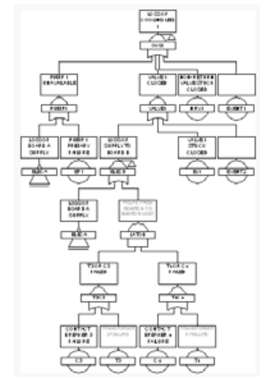
Model-based Engineering Pitfalls

The system

Inconsistency between independently developed analytical models

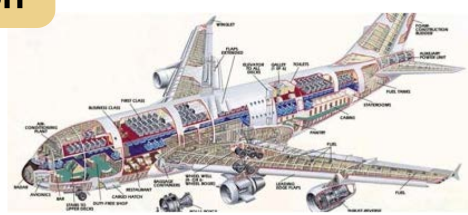






System models

Confidence that model reflects implementation



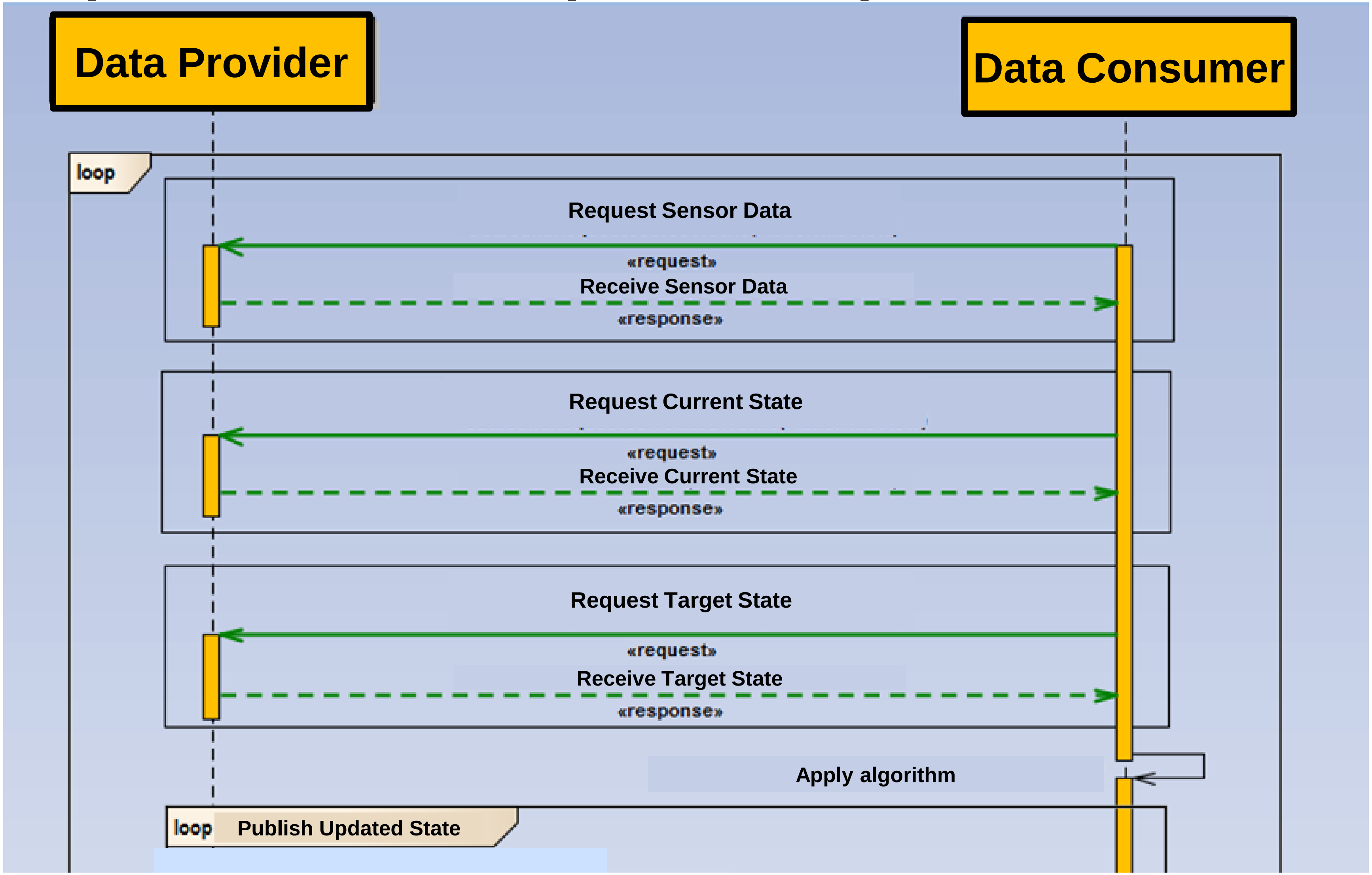
System implementation

This aircraft industry experience has led to the System Architecture Virtual Integration (SAVI) initiative

Why UML, SysML Are Not Sufficient

- System engineering
  - Focus on system architecture and operational environment
  - SysML developed to capture interactions with outside world, as a standardized UML profile
  - 4 pillars/diagrams: requirements, parameterics (added in SysML), structure, behavior
- Conceptual architecture
  - UML-based component model
  - Architecture views (DoDAF, IEEE 1471)
  - Platform Independent model (PIM)
- Embedded software system engineering
  - OMG Modeling and Analysis of Real Time Embedded systems (MARTE) as UML profile
    - Borrowed Meta model concepts from AADL
    - Focus on modeling implementations
  - xUML insufficient for PSM (Kennedy-Carter, NATO ALWI study)

Impact of Three Step Data Request Protocol



Operating as ARINC653 Partitioned System

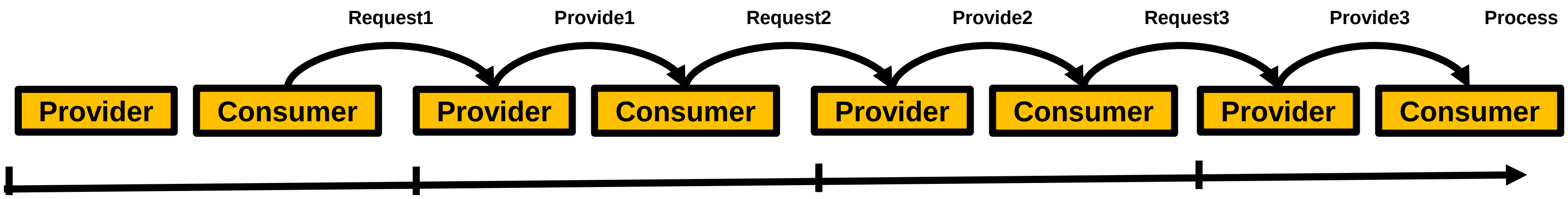
Data Consumer Requirement

- Process data in 1 second

Partitions

- Provide space and time boundary enforcement
- Execute periodically on a static timeline at 1 second rate

Data request protocols across partitions



How much time does consumer actually have to process the data?

Who pays for the communication overhead?

Model-based Engineering in Practice

Modeling is used in practice

- Modeling, analysis, and simulation in mechanical, control, computer hardware engineering

Current practice: software modeling close to source code

  – Remember software through pictures
  – MDE and MDA with UML
  – Automatically generated documents

We need language for architecture modeling and analysis

- Strongly typed
- Well-defined execution and communication timing semantics
- Systematic approach to dealing with exceptional conditions
- Support for large-scale development

Outline

Challenges in Safety-critical Software-intensive systems

An Architecture-centric Virtual Integration Strategy with SAE AADL

Improving the Quality of Requirements

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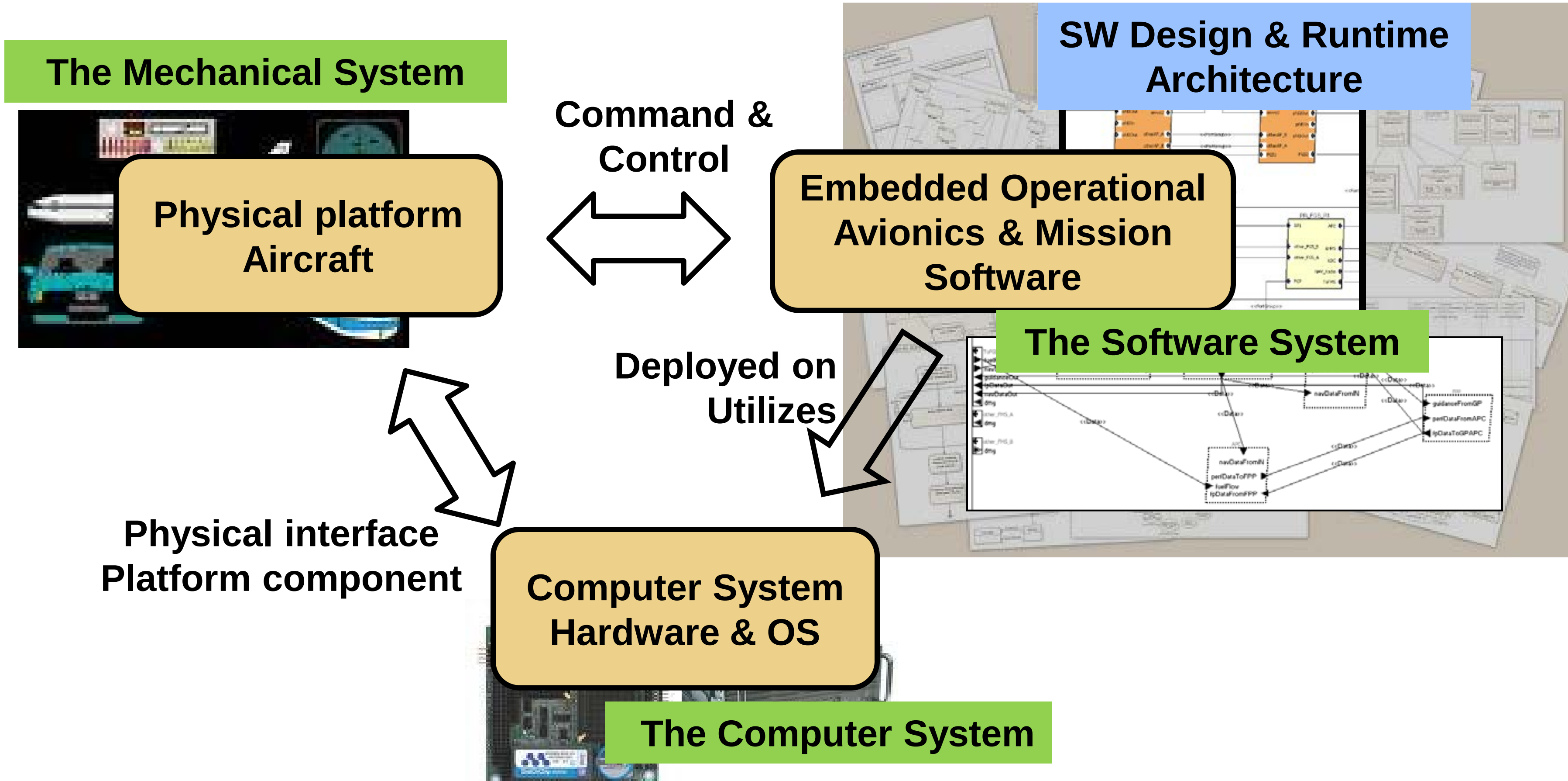
Incremental Life-cycle Assurance of Systems

Summary and Conclusion

SAE Architecture Analysis & Design Language (AADL) for Software-reliant Systems



AADL focuses on interaction between the three elements of a software-reliant mission and safety-critical systems.

The SAE AADL Standard Suite (AS-5506 series)

Core AADL language standard (V2.1-Sep 2012, V1-Nov 2004)

- Strongly typed language with well-defined execution and communication semantics
- Textual and graphical notation
- Standardized XMI interchange format

Standardized AADL Extensions

Error Model language for safety, reliability, security analysis
ARINC653 extension for partitioned architectures
Behavior Specification Language for modes and interaction behavior
Data Modeling extension for interfacing with data models (UML, ASN.1, …)

AADL Annex Extensions in Progress

Requirements Definition and Assurance Annex
Synchronous System Specification Annex
Hybrid System Specification Annex
System Constraint Specification Annex
Network Specification Annex

AADL: The Language

Precise execution semantics for components

- Thread, process, data, subprogram, system, processor, memory, bus, device, virtual processor, virtual bus

Continuous control & event response processing

- Data and event flow, call/return, shared access
- End-to-End flow specifications

Operational modes & fault tolerant configurations

- Modes & mode transition

Modeling of large-scale systems

- Component variants, layered system modeling, packages, abstract, prototype, parameterized templates, arrays of components, connection patterns

Accommodation of diverse analysis needs

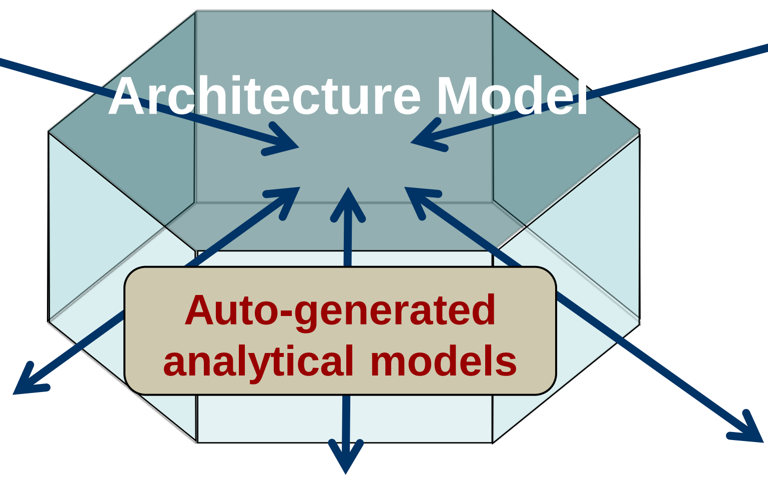
- Extension mechanism, standardized extensions

Architecture-Centric Quality Attribute Analysis

Single Annotated Architecture Model Addresses Impact Across Operational Quality Attributes

Safety & Reliability
- MTBF
- FMEA
- Hazard analysis

Security
- Intrusion
- Integrity
- Confidentiality

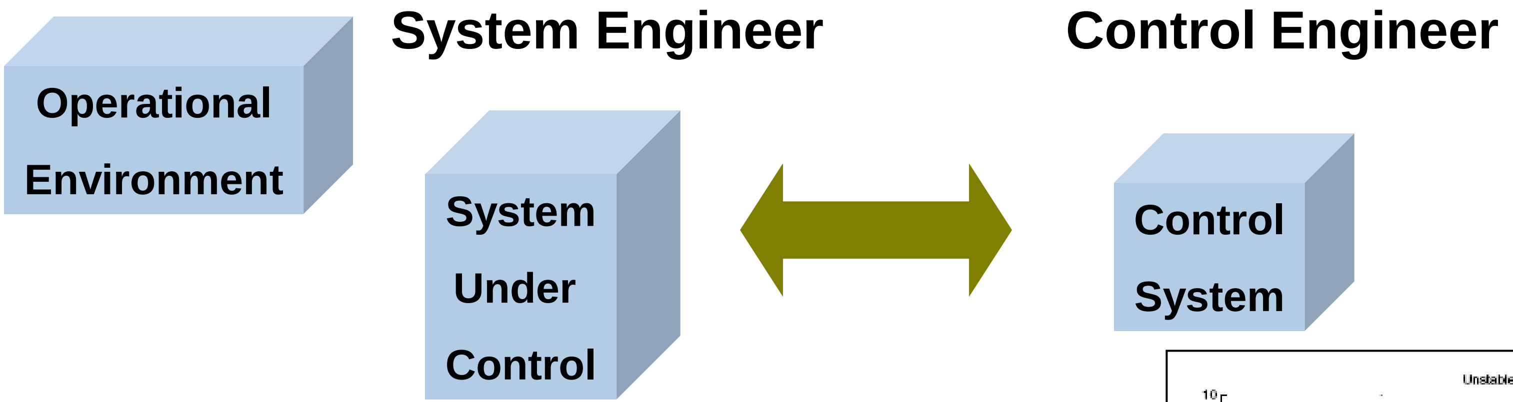


Data Quality
- Data precision/ accuracy
- Temporal correctness
- Confidence

Real-time Performance
- Execution time/ Deadline
- Deadlock/starvation
- Latency

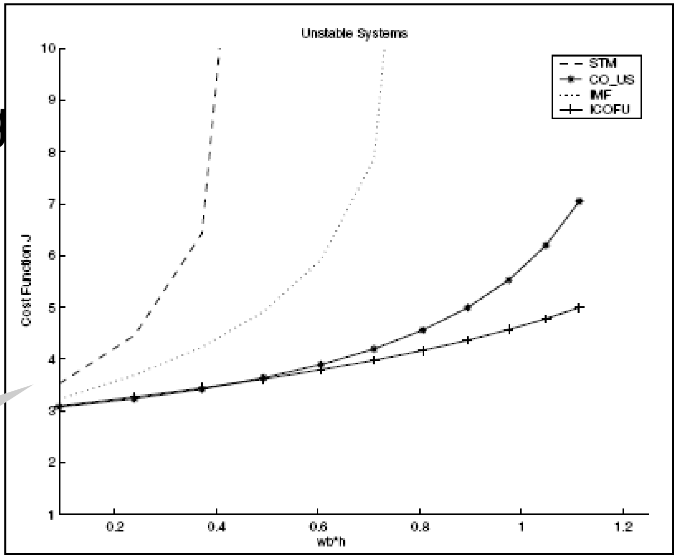
Resource Consumption
- Bandwidth
- CPU time
- Power consumption

Multi-Fidelity End-to-end Latency in Control Systems



Common latency data from system engineering

- Processing latency
- Sampling latency
- Physical signal latency

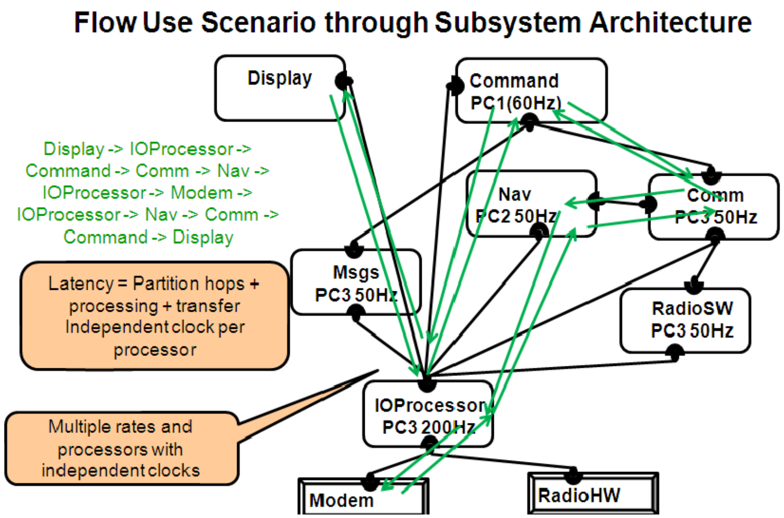


Impact of Scheduler Choice on Controller Stability

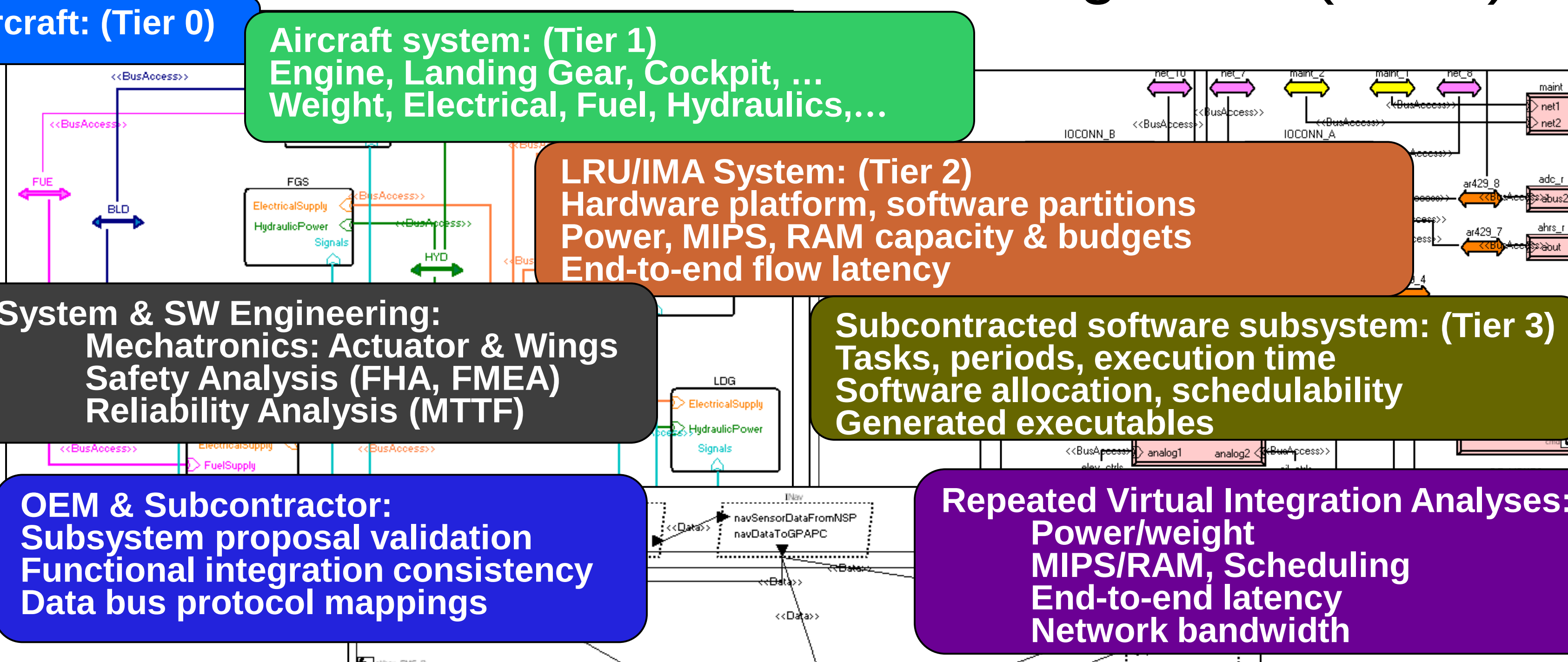
A. Cervin, Lund U., CCACSD 2006

Software-Based Latency Contributors

- Execution time variation: algorithm, use of cache
- Processor speed
- Resource contention
- Preemption
- Legacy & shared variable communication
- Rate group optimization
- Protocol specific communication delay
- Partitioned architecture
- Migration of functionality
- Fault tolerance strategy



Early Discovery and Incremental V&V through System Architecture Virtual Integration (SAVI)



Aircraft: (Tier 0)

Aircraft system: (Tier 1)
Engine, Landing Gear, Cockpit, …
Weight, Electrical, Fuel, Hydraulics,…

LRU/IMA System: (Tier 2)
Hardware platform, software partitions
Power, MIPS, RAM capacity & budgets
End-to-end flow latency

System & SW Engineering:
- **Mechatronics: Actuator & Wings**
- **Safety Analysis (FHA, FMEA)**
- **Reliability Analysis (MTTF)**

Subcontracted software subsystem: (Tier 3)
Tasks, periods, execution time
Software allocation, schedulability
Generated executables

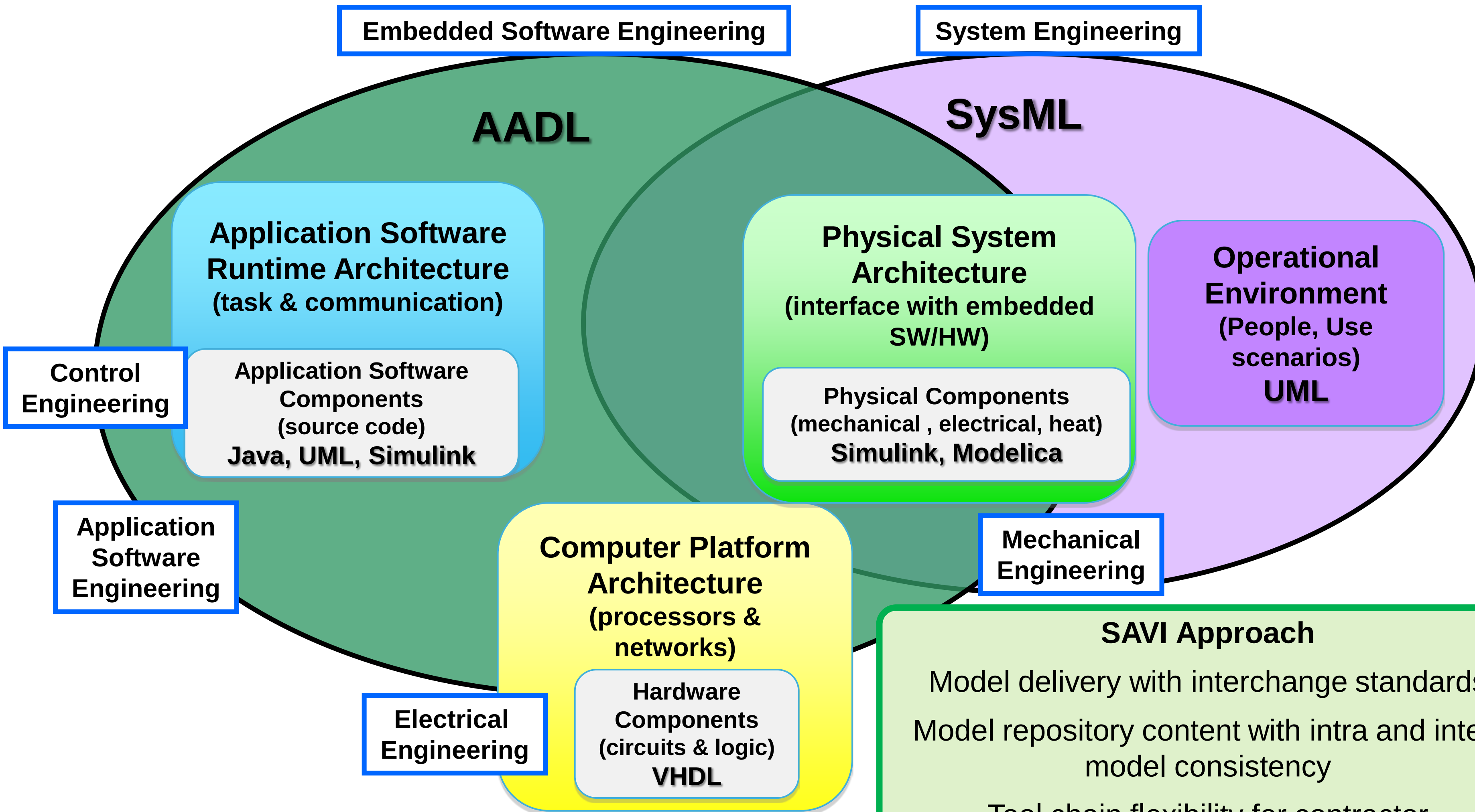
OEM & Subcontractor:
Subsystem proposal validation
Functional integration consistency
Data bus protocol mappings

Repeated Virtual Integration Analyses:
- **Power/weight**
- **MIPS/RAM, Scheduling**
- **End-to-end latency**
- **Network bandwidth**

Proof of Concept Demonstration and Transition by Aerospace industry initiative
- **Architecture-centric model-based software and system engineering**
- **Architecture-centric model-based acquisition and development process**
- **Multi notation, multi team model repository & standardized model interchange**

- Multi-tier system & software architecture (in AADL)
- Incremental end-to-end validation of system properties

Multi-Notation Approach to Architecture-centric Virtual System and Software Integration



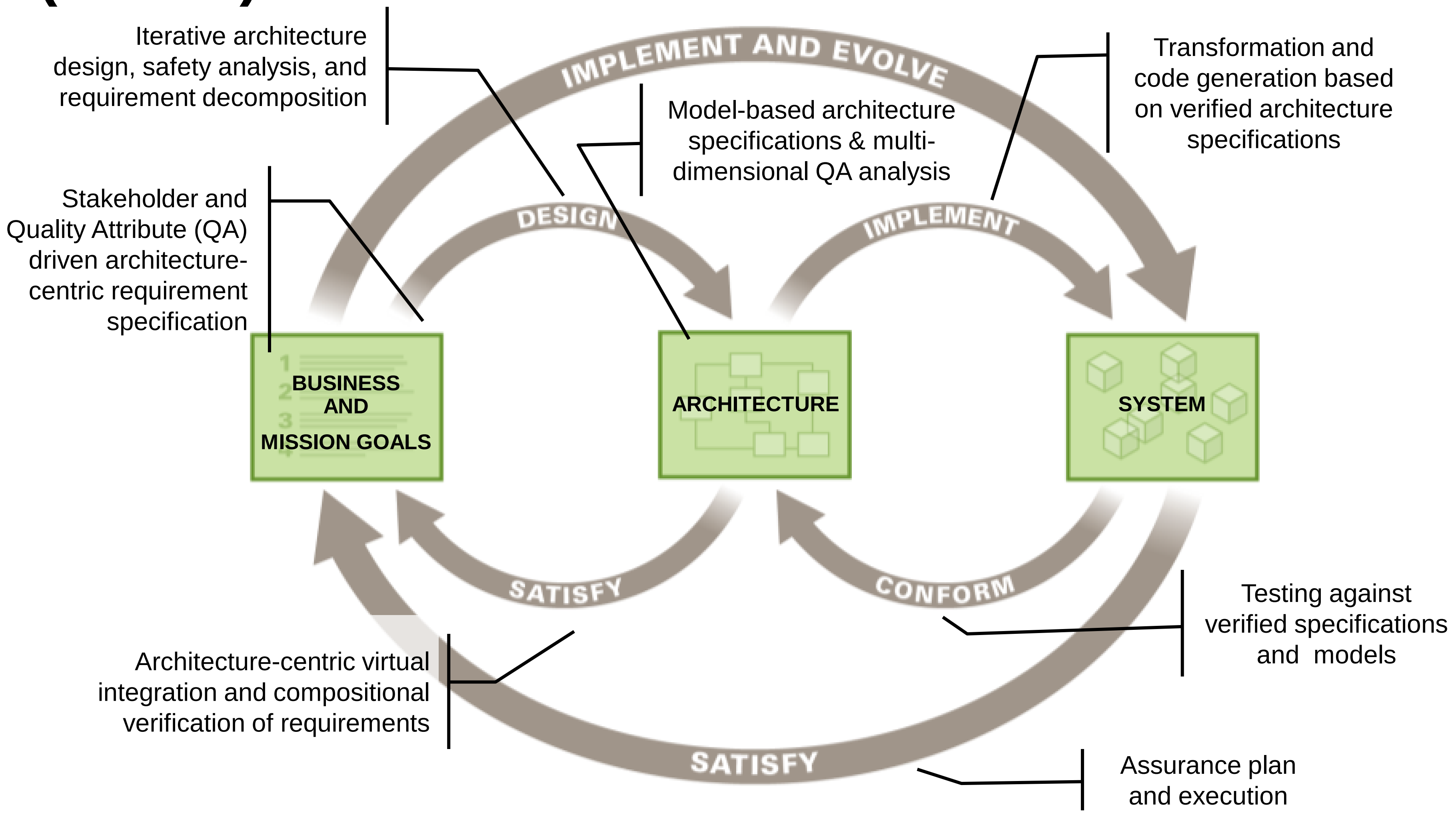
SAVI Approach

Model delivery with interchange standards

Model repository content with intra and inter-model consistency

Tool chain flexibility for contractor

Architecture-centric Virtual Integration Practice (ACVIP)



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Certification & Recertification Challenges

Certification: assure the quality of the delivered system

- Sufficient evidence that a system implementation meets system requirements
- Quality of requirements and quality of evidence determines quality of system

Certification related rework cost

- Currently 50% of total system cost and growing

Recertification Challenge

- Desired cost of recertification in proportion to change

Improve quality of requirements and evidence

Perform verification compositionally
throughout the life cycle

Industry Practice in DO-178B Compliant Requirements Capture

Industry Survey in 2009 FAA Requirements Engineering Study

Notation

Enter an "x" in every row/column cell that applies	System Requirements	Data Interconnect {ICD}	High-Level Software Requireme	Low-Level Software Requireme	Hardware Requirements
English Text or Shall Statements	39	27	36	32	29
Tables and Diagrams	31	30	30	19	18
UML Use Cases	1		2	4	
UML Sequence Diagrams			3	6	
UML State Diagrams			1	7	
Executable Models (e.g. Simulink, SCADE Suite, etc.)	7	1	8	8	1
Data Flow Diagrams (e.g. Yourdon)	4		6	9	
[illegible]					
Other (Specify)XML		1			
Operational models or prototypes	1	1			1
UML			1	1	

Need analyzable & executable specifications

Tool

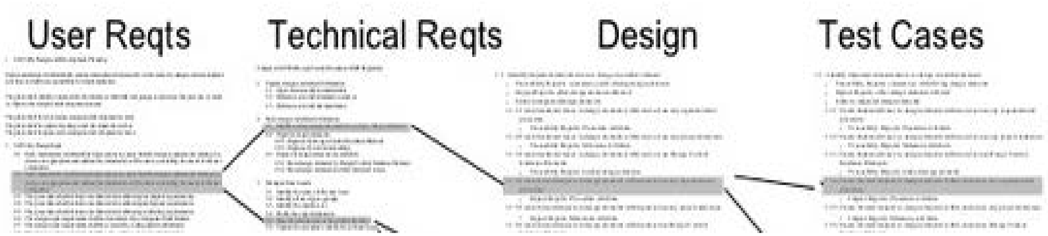
Enter an "x" in every row/column cell that applies	System Requirements	Data Interconnect {ICD}	High-Level Software Requirements	Low-Level Software Requirements	Hardware Requirements
Database (e.g., Microsoft Access)	3	4	3	3	
DOORS	23	13	22	18	12
Rational ROSE®			1	3	
RDD-100®					
Requisite Pro®	5	3	5	4	4
Rhapsody	1				
SCADE Suite	2		3	1	
Simulink	5	1	5	3	1
Slate	1		1	1	
Spreadsheet (e.g., Microsoft Excel)	5	4	5	4	3
Statemate					
Word Processor (e.g., Microsoft Word)	19	20	18	17	16
VAPS™		1	3	3	
Designer's Workbench™			1	1	
Proprietary Database, SCADE like pic tool		1	1		
Interleaf	1	1	1	1	1
BEACON	1	1	1	1	
CaliberRM	1	1	1	1	1
XM:		1			
Wiring diagram		1			1

Requirement Quality Challenge

Requirements error	%
Incomplete	21%
Missing	33%
Incorrect	24%
Ambiguous	6%
Inconsistent	5%

There is more to requirements quality than "shall"s and stakeholder traceability

IEEE 830-1998 Recommended Practice for SW Requirements Specification



Browsable links/Coverage metrics

IEEE Std 830-1998 characteristics of a good requirements specification:

- Correct
- Unambiguous
- Complete
- Consistent
- Ranked for importance and/or stability
- Verifiable
- Modifiable
- Traceable

System to SW requirements gap [Boehm 2006]

How do we verify low level SW requirements against system requirements?

When StartUpComplete is TRUE in both FADECs and SlowStartupComplete is FALSE, the FADECStartupSW shall set SlowStartupInComplete to TRUE

Stakeholder Needs and Requirement Categories

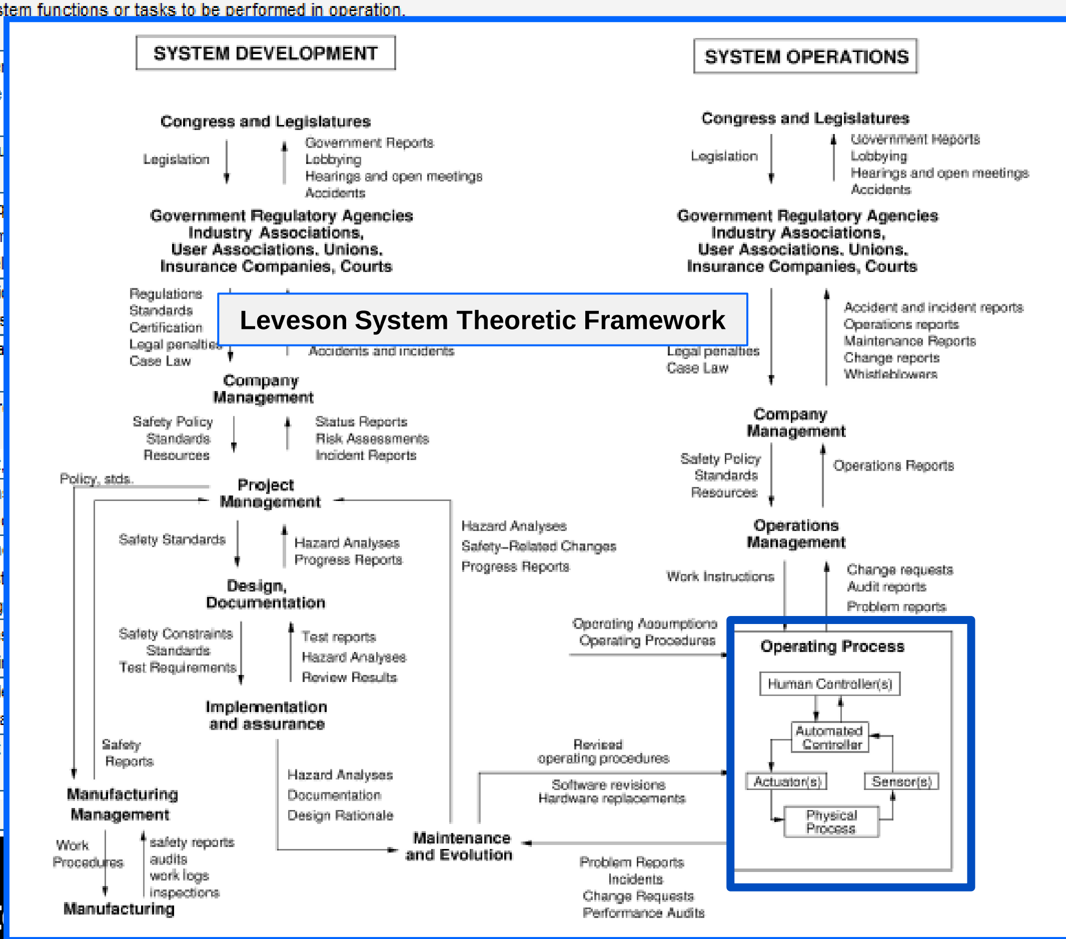
ISO/IEC/IEEE. 2011. *Systems and Software Engineering - Requirements Engineering*. Geneva, Switzerland: International Organization for Standardization (ISO)/International Electrotechnical Commission/ Institute of Electrical and Electronics Engineers (IEEE), (IEC), ISO/IEC/IEEE 29148.

Table 2. Example of Stakeholder Requirements Classification. (SEBoK Original)

Type of Stakeholder Requirement	
Service or Functional	Sets of actio
Operational	This categor • Operatio • Operatio • Operatio of-intere
Interface	Matter, energ
Environmental	External con
Utilization Characteristics	The '-ilities' u
Human Factors	Capabilities c
Logistical	Acquisition, t
Design and Realization Constraints	Reuse of ex
Process Constraints	These are st system, but laws, admini corporate po agreement d
Project Constraints	Constraints t
Business Model Constraints	Constraints (local, nation revenue model, etc.

Table 2. Example of System Requirements Classification. (SEBoK Original)

Types of System Requirement	Description
Functional Requirements	Describe qualitatively the system functions or tasks to be performed in operation.
Performance Requirements	Define quantitatively the exte system performance and are or task.
Usability Requirements	Define the quality of system u
Interface Requirements	Define how the system is req system, including human elem systems or internal system el
Operational Requirements	Define the operational conditi maintainability, reliability, and s
Modes and/or States Requirements	Define the various operationa
Adaptability Requirements	Define potential extension, gr
Physical Constraints	Define constraints on weight,
Design Constraints	Define the limits on the option provided system element, or
Environmental Conditions	Define the environmental con temperature, fauna, salt, dust societal environment (e.g. leg
Logistical Requirements	Define the logistical conditions personnel, spare parts, trainin
Policies and Regulations	Define relevant and applicabl regulatory agony, health or sa
Cost and Schedule Constraints	Define, for example, the cost



System, operational environment, development and V&V process

Mixture of Requirements & Architecture Design Constraints

Requirements for a Patient Therapy System

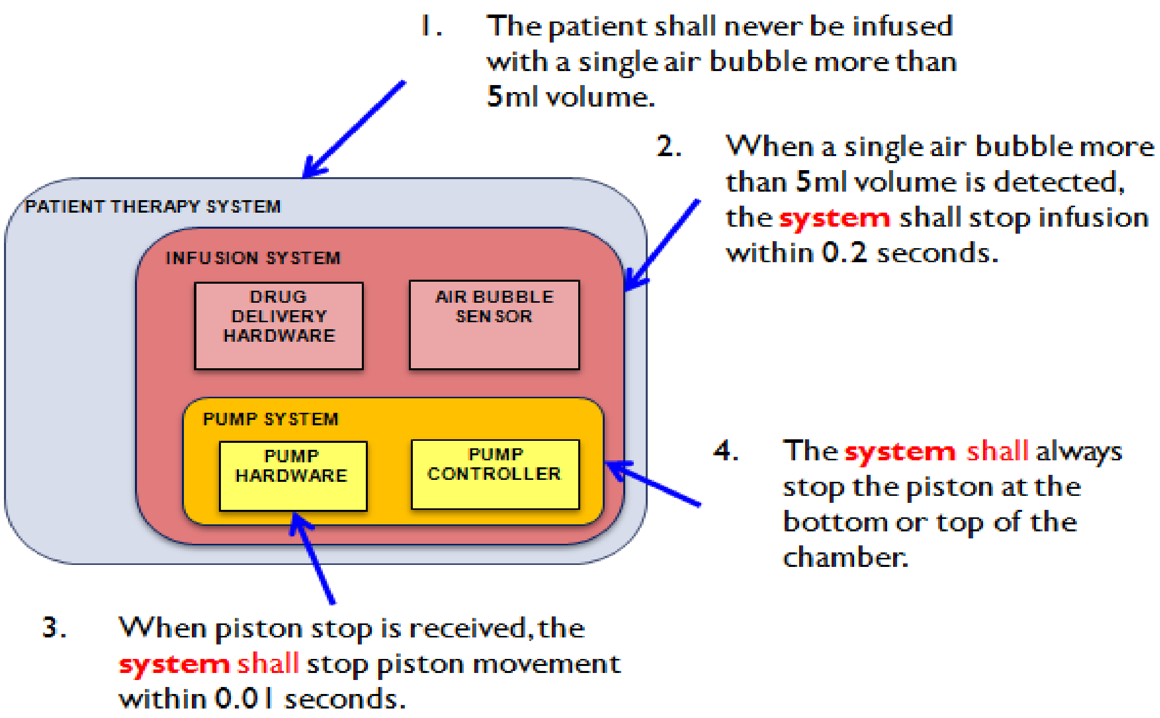
The patient shall never be infused with a single air bubble more than 5ml volume.

When a single air bubble more than 5ml volume is detected, the **system** shall stop infusion within 0.2 seconds.

When piston stop is received, the **system** shall stop piston movement within 0.01 seconds.

The **system** shall always stop the piston at the bottom or top of the chamber.

Requirements and Design Information



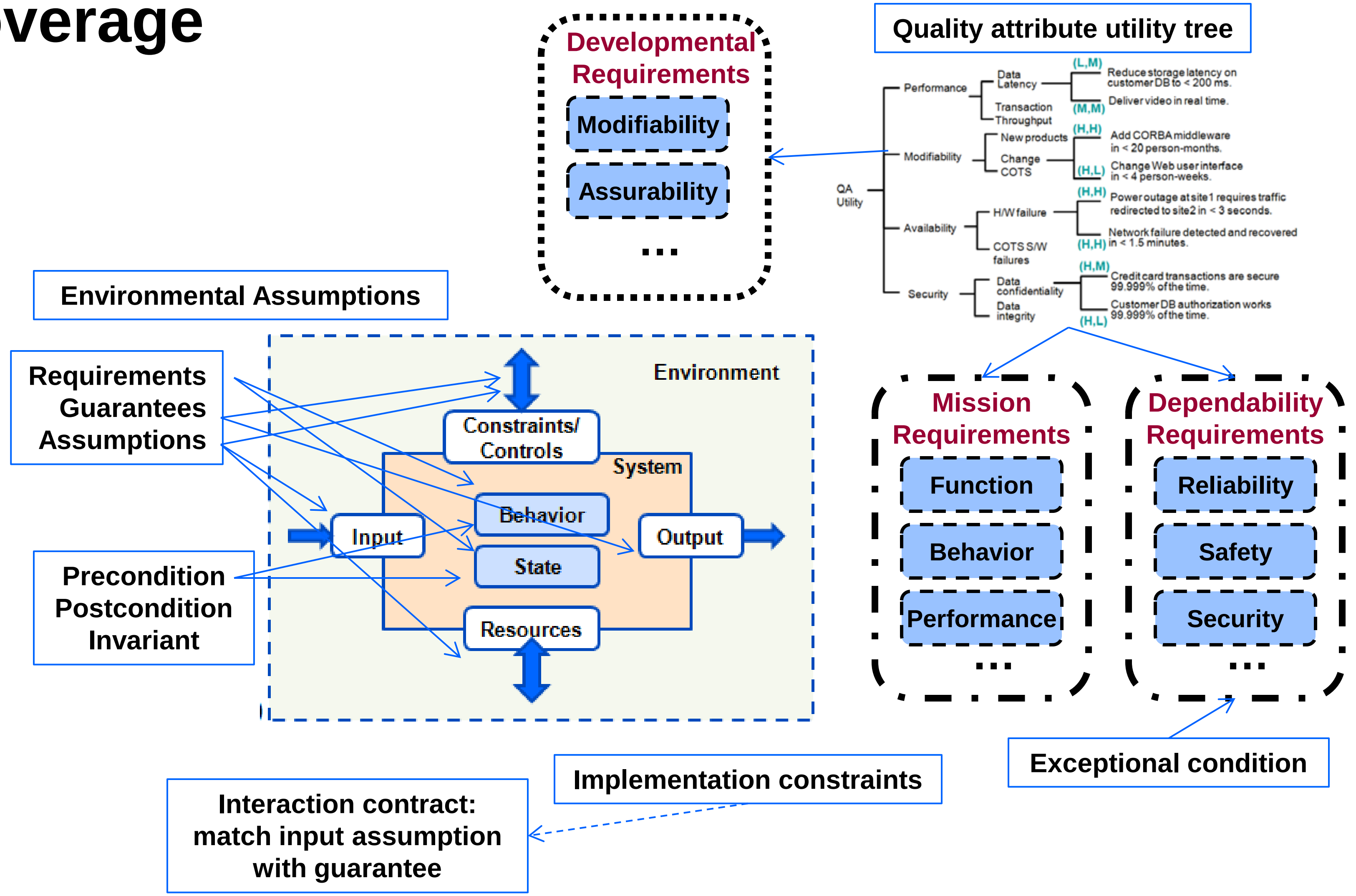
Typical requirement documents span multiple levels of a system architecture

We have made architecture design decisions.

We have effectively *specified a <u>partial architecture</u>*

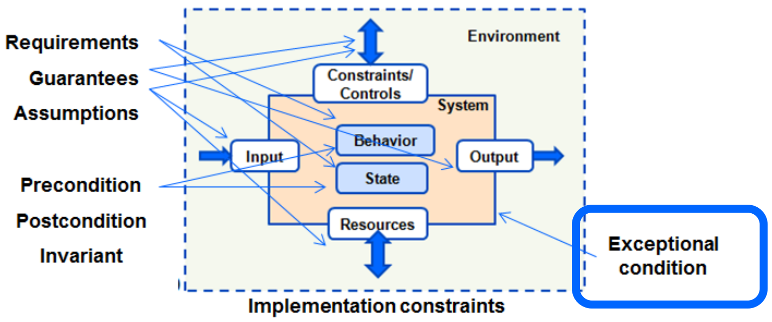
Adapted from M. Whalen presentation

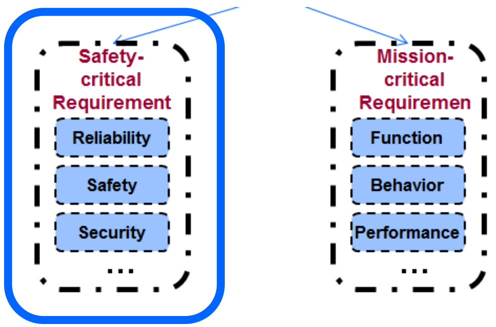
System Specification and Requirements Coverage



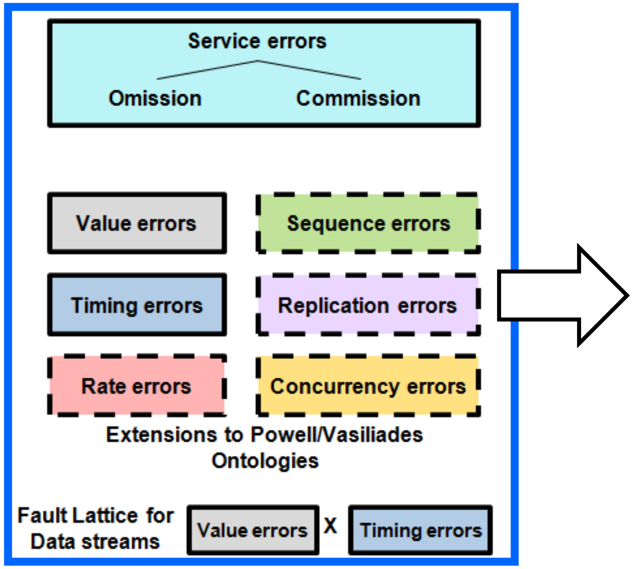
Architecture-led Requirement & Hazard Specification

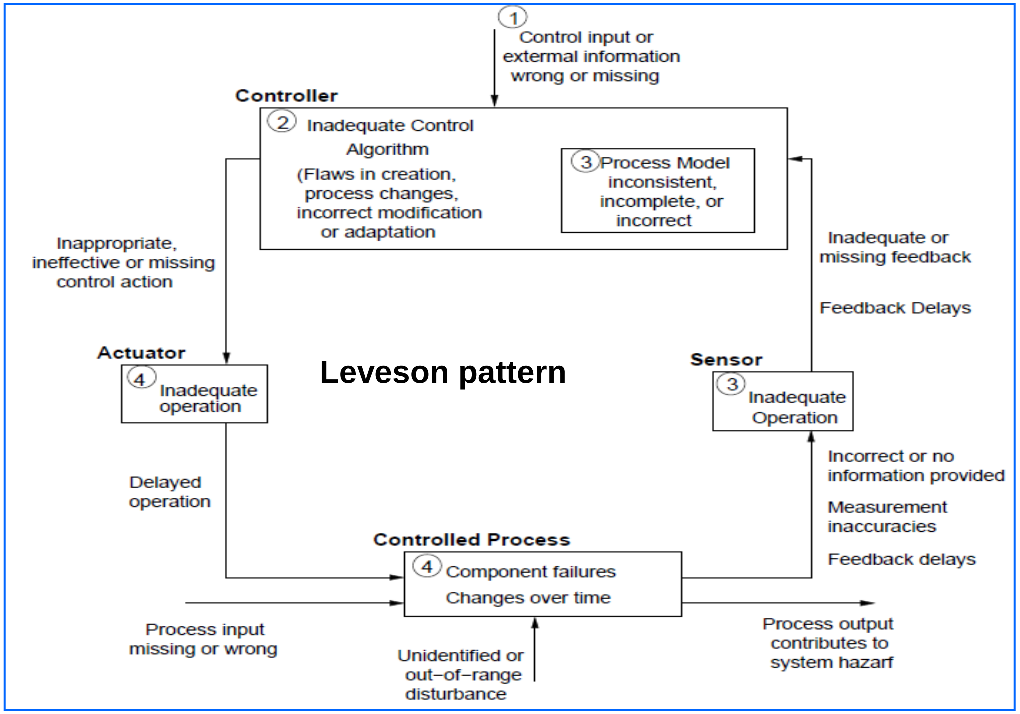
System Specification Coverage





Error Propagation Ontology





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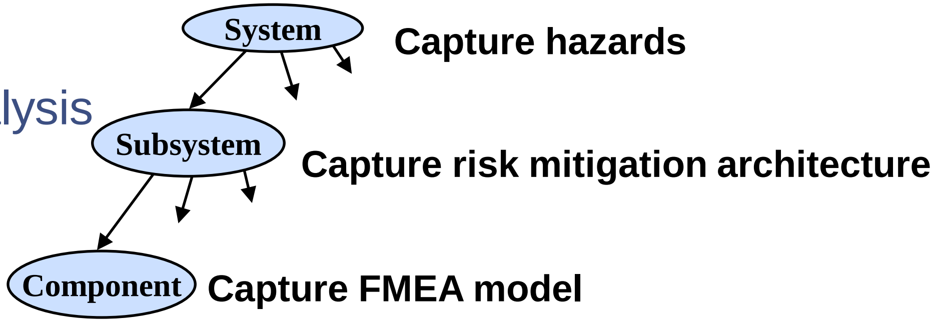
AADL Error Model Scope and Purpose

System safety process uses many individual methods and analyses, e.g.

- hazard analysis
- failure modes and effects analysis
- fault trees
- Markov processes



Goal: a general facility for modeling fault/error/failure behaviors that can be used for several modeling and analysis activities.

Annotated architecture model permits checking for consistency and completeness between these various declarations.

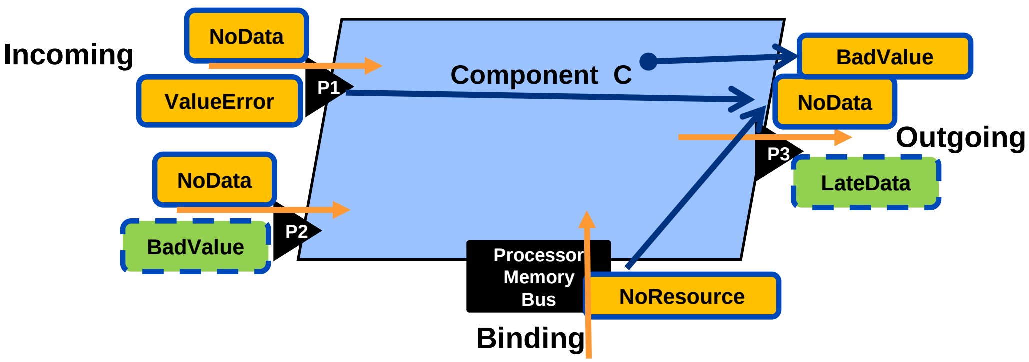
Related analyses are also useful for other purposes, e.g.

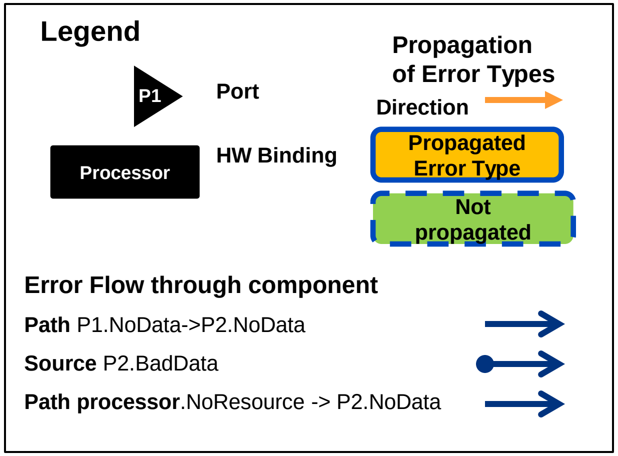
- maintainability
- availability
- Integrity
- Security

SAE ARP 4761 *Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment*
Demonstrated in SAVI Wheel Braking System Example

Error Model Annex can be adapted to other ADLs

Error Propagation Contracts





“Not“ on propagated indicates that this error type is intended to be contained.

This allows us to determine whether propagation specification is complete.

Incoming/Assumed

- **Error Propagation**
  Propagated errors
- **Error Containment:**
  Errors not propagated

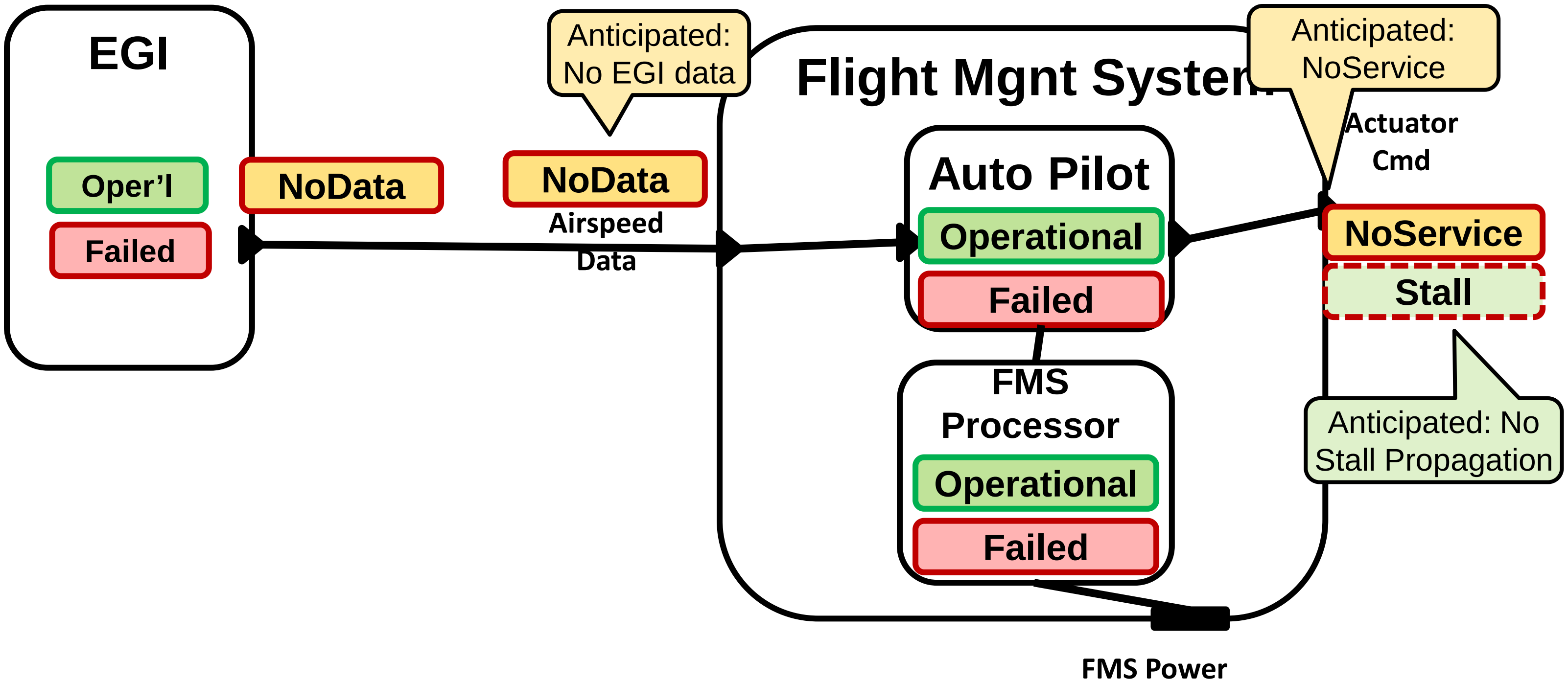
Outgoing/Contract

- **Error Propagation**
- **Error Containment**

Bound resources

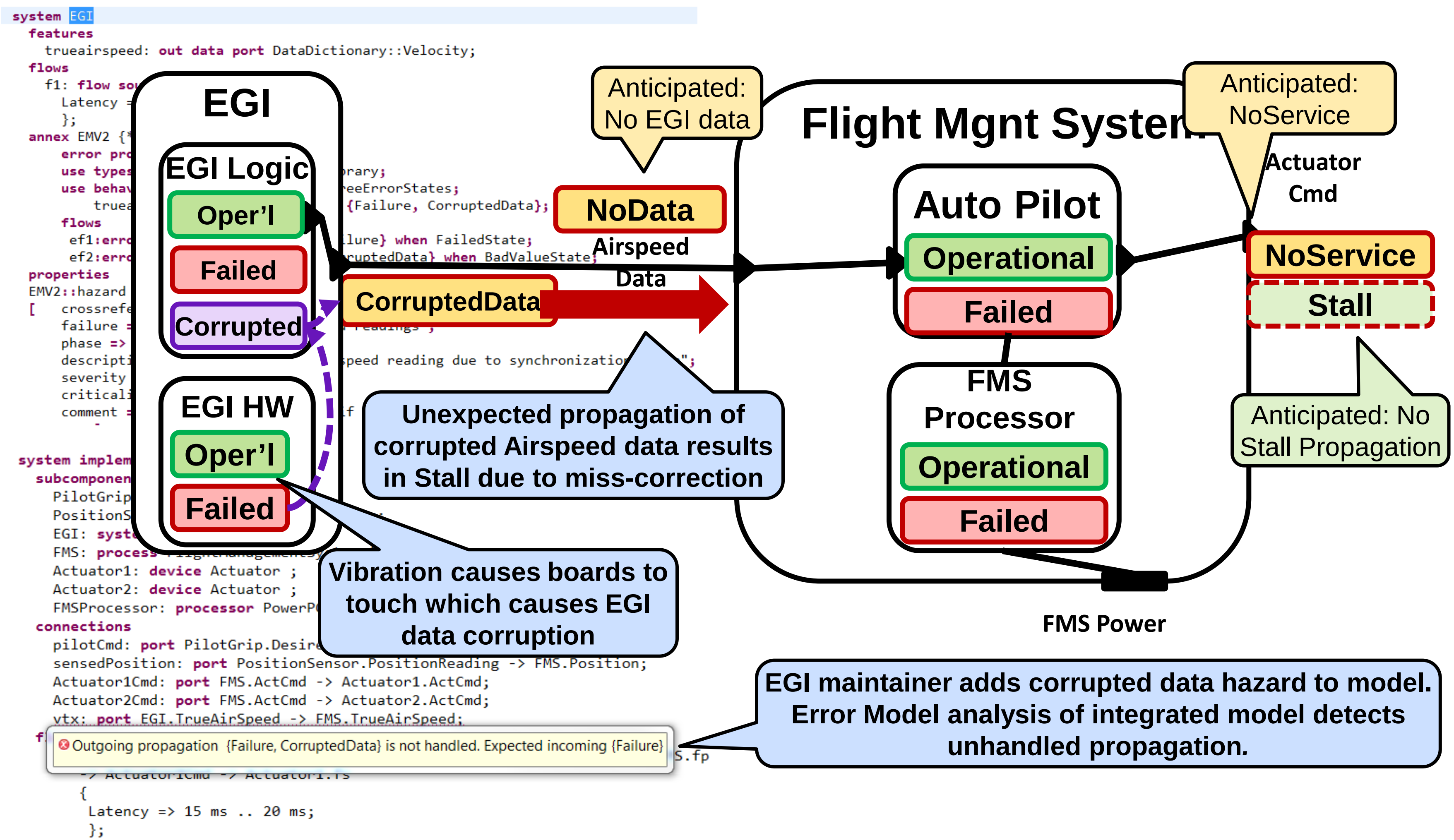
- **Error Propagation**
- **Error Containment**
- **Propagation to resource**

Original Preliminary System Safety Analysis (PSSA)



System engineering activity with focus on failing components.

Discovery of Unexpected PSSA Hazard through Repeated Virtual Integration



Recent Automated FMEA Experience

Failure Modes and Effects Analyses are rigorous and comprehensive reliability and safety design evaluations

- Required by industry standards and Government policies
- When performed manually are usually done once due to cost and schedule
- If automated allows for
  - multiple iterations from conceptual to detailed design
  - Tradeoff studies and evaluation of alternatives
  - Early identification of potential problems

ID	Item	Initial State	Initial Failure Mode	1st Level Effect	Transition	2nd Level Effect	Transition	3rd Level Effect	Severity	M
1	Sat_Bus	Working	Failure	Failed		Failed	Recovery	Working		Workir
1	Sat_Payload	Working		Working	Bus failure causes payload transition	Standby		Standby	Bus Recovery Causes Payload Transition	Workir
2	Sat_Bus	Working		Working		Working	5			
2	Sat_Payload	Working	Failure	Failed	Recovery	Working	5			

Largest analysis of satellite to date consists of 26,000 failure modes

- Includes detailed model of satellite bus
- 20 states perform failure mode
- Longest failure mode sequences have 25 transitions (i.e., 25 effects)

Myron Hecht, Aerospace Corp.
Safety Analysis for JPL, member of DO-178C committee

Outline

Challenges in Safety-critical Software-intensive systems

An Architecture-centric Virtual Integration Strategy with SAE AADL

Improving the Quality of Requirements

Architecture Fault Modeling and Safety

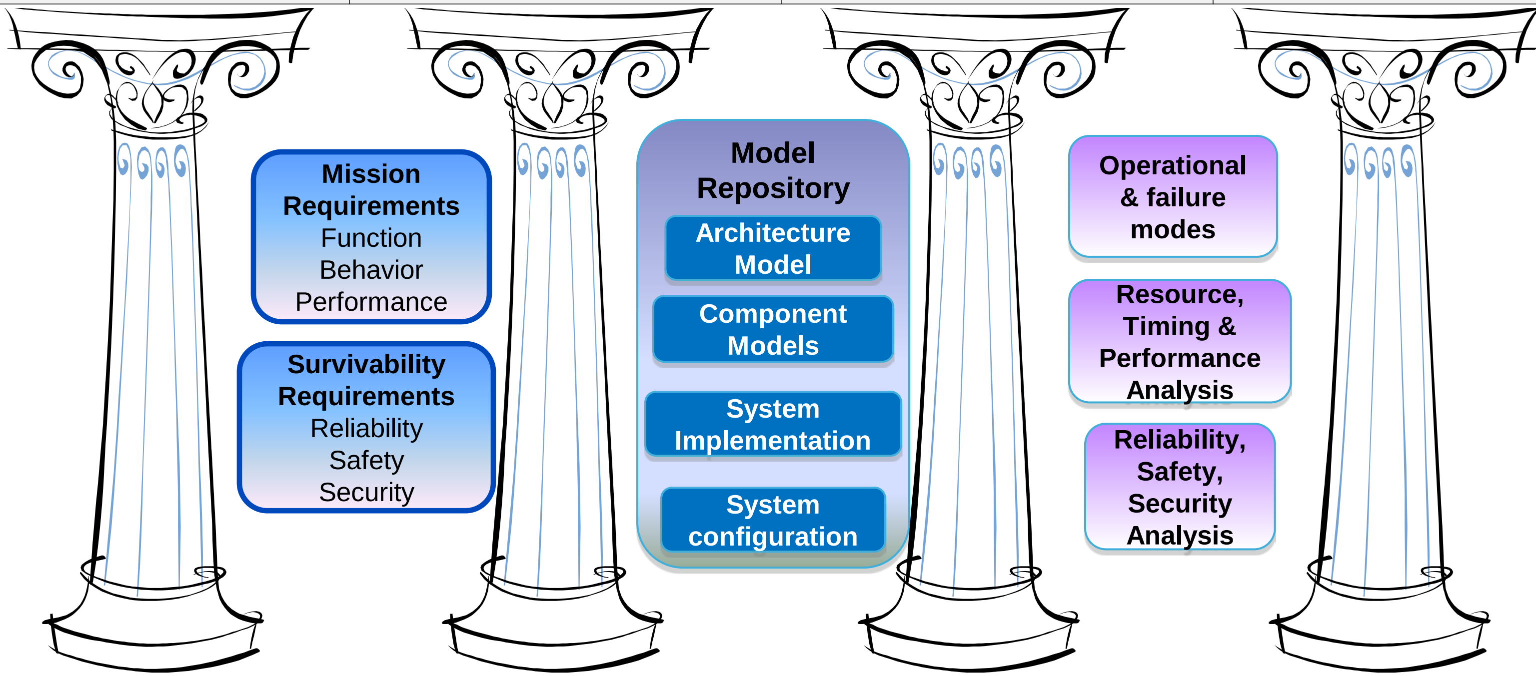
Incremental Life-cycle Assurance of Systems

Summary and Conclusion

Reliability & Qualification Improvement Strategy

2010 SEI Study for AMRDEC
Aviation Engineering Directorate

Architecture-led Requirement Specification	Architecture-centric Virtual System Integration	Static Analysis & Compositional Verification	Incremental Assurance Plans & Cases throughout Life Cycle



Four pillars for Improving Quality of Critical Software-reliant Systems

Verification Actions

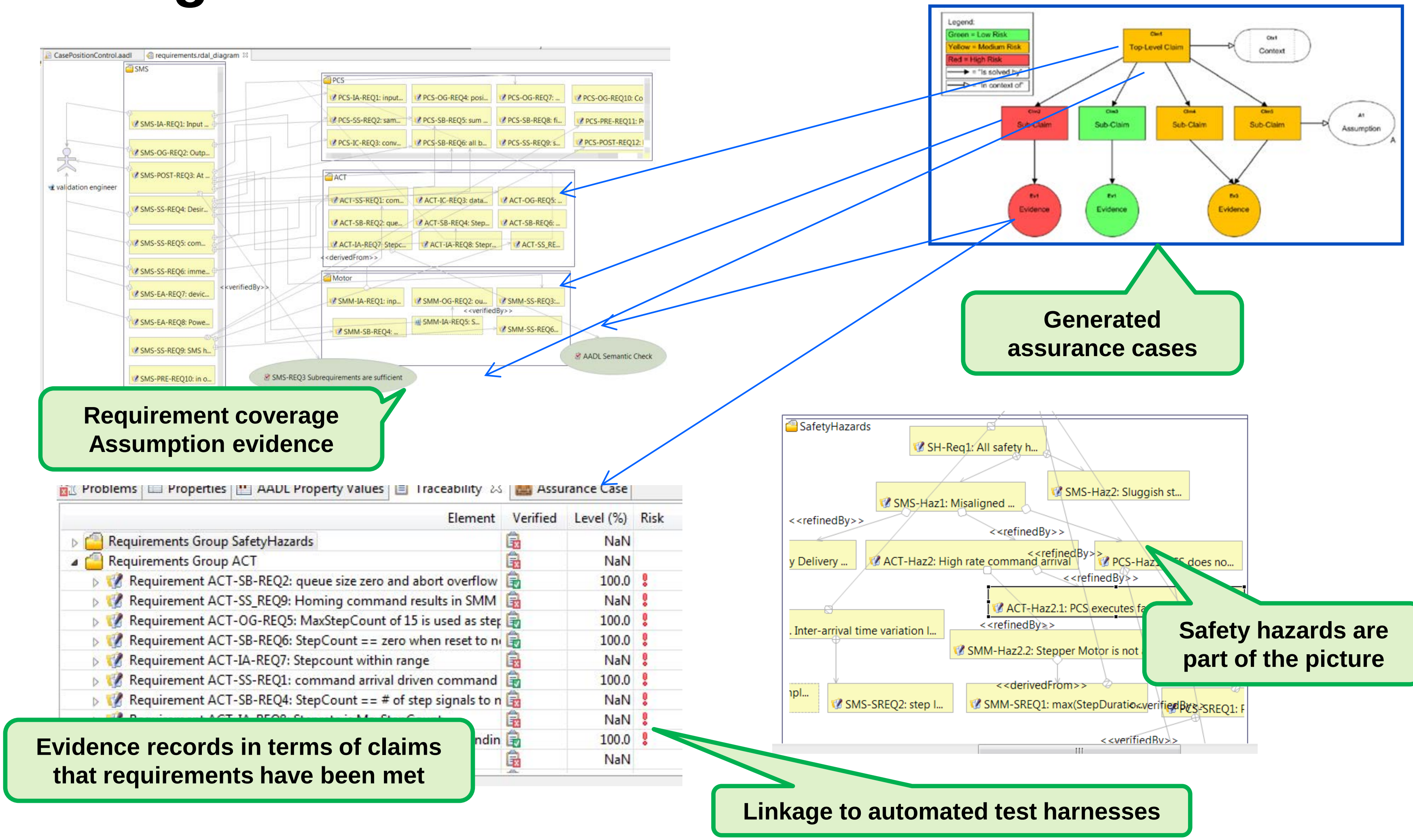
Table 2. Main Ontology Elements as Handled within Verification. (SEBoK Original)

Element	Definition / Attributes (examples)
Verification Action	A verification action describes what must be verified (the element as reference), on which element, the expected result, the verification technique to apply, on which level of decomposition. Identifier, name, description
Verification Procedure	A ve Ider
Verification Tool	A ve Ider
Verification Configuration	A ve proc Ider
Risk	An (use
Rationale	An Ider

Table 3. Verification Techniques. (SEBoK Original)

Verification Technique	Description
Inspection	Technique based on visual or dimensional examination of an element; the verification relies on the human senses or uses simple methods of measurement and handling. Inspection is generally non-destructive, and typically includes the use of sight, hearing, smell, touch, and taste, simple physical manipulation, mechanical and electrical gauging, and measurement. No stimuli (tests) are necessary. The technique is used to check properties or characteristics best determined by observation (e.g. - paint color, weight, documentation, listing of code, etc.).
Analysis	Technique based on analytical evidence obtained without any intervention on the submitted element using mathematical or probabilistic calculation, logical reasoning (including the theory of predicates), modeling and/or simulation under defined conditions to show theoretical compliance. Mainly used where testing to realistic conditions cannot be achieved or is not cost-effective.
Analogy or Similarity	Technique based on evidence of similar elements to the submitted element or on experience feedback. It is absolutely necessary to show by prediction that the context is invariant that the outcomes are transposable (models, investigations, experience feedback, etc.). Similarity can only be used if the submitted element is similar in design, manufacture, and use; equivalent or more stringent verification actions were used for the similar element, and the intended operational environment is identical to or less rigorous than the similar element.
Demonstration	Technique used to demonstrate correct operation of the submitted element against operational and observable characteristics without using physical measurements (no or minimal instrumentation or test equipment). Demonstration is sometimes called 'field testing'. It generally consists of a set of tests selected by the supplier to show that the element response to stimuli is suitable or to show that operators can perform their assigned tasks when using the element. Observations are made and compared with predetermined/expected responses. Demonstration may be appropriate when requirements or specification are given in statistical terms (e.g. meant time to repair, average power consumption, etc.).
Test	Technique performed onto the submitted element by which functional, measurable characteristics, operability, supportability, or performance capability is quantitatively verified when subjected to controlled conditions that are real or simulated. Testing often uses special test equipment or instrumentation to obtain accurate quantitative data to be analyzed.
Sampling	Technique based on verification of characteristics using samples. The number, tolerance, and other characteristics must be specified to be in agreement with the experience feedback.

Integrated Approach to Requirement V&V through Assurance Automation



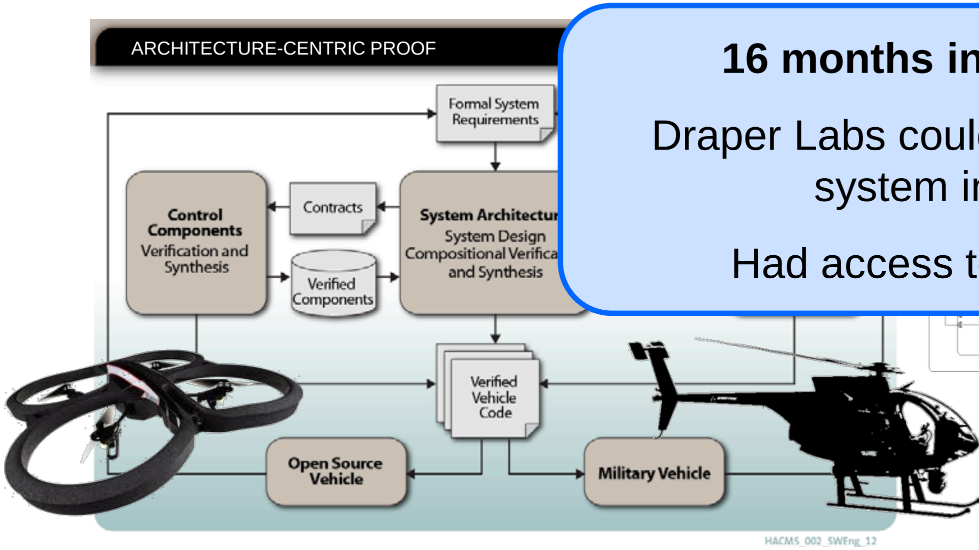
Contract-based Compositional Verification

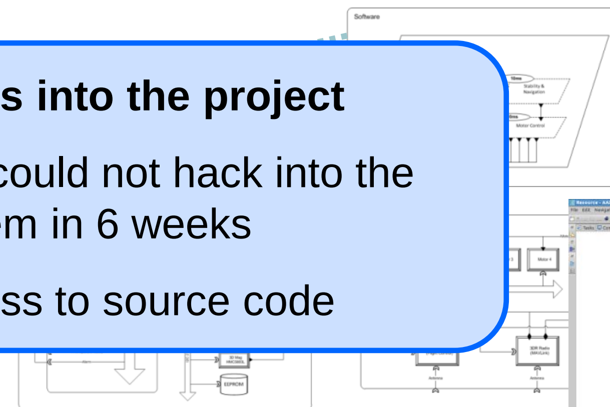
Secure Mathematically-Assured Composition of Control Models

Key Problem

Many vulnerabilities occur at component interfaces. How can we use formal methods to detect these vulnerabilities and build provably secure systems?

TA4 – Research Integration and Formal Methods Workbench
Rockwell Collins and University of Minnesota

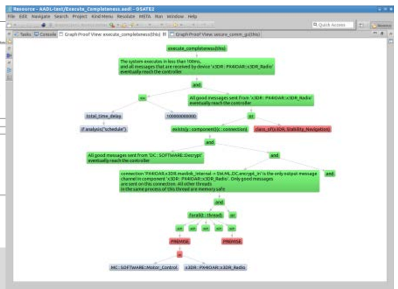




16 months into the project

Draper Labs could not hack into the system in 6 weeks

Had access to source code



Technical Approach

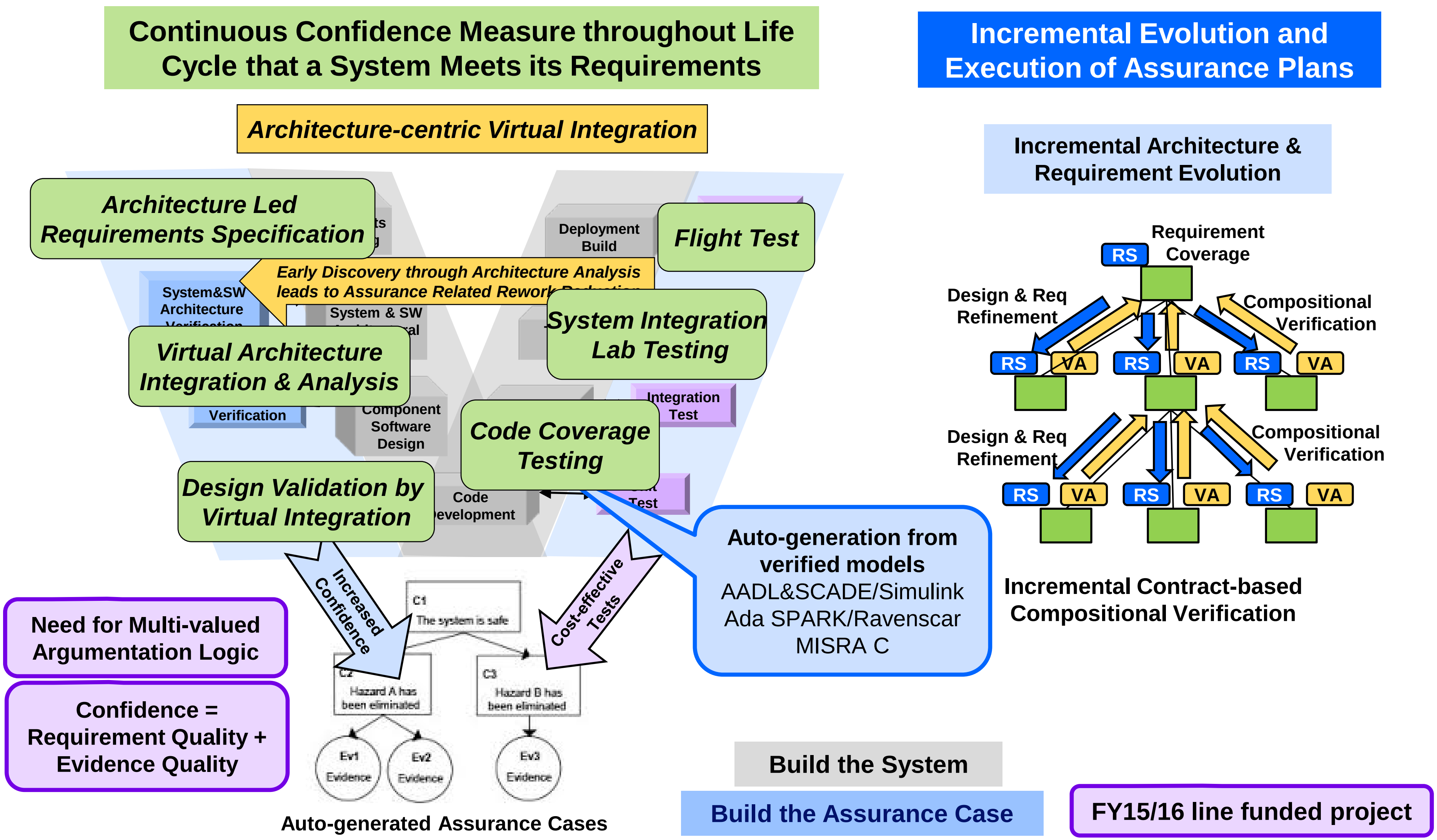
- Develop a complete, formal architecture model for UAVs that provides robustness against cyber attack
- Develop compositional verification tools driven from the architecture model for combining formal evidence from multiple sources, components, and subsystems
- Develop synthesis tools to generate flight software for UAVs directly from the architecture model, verified components, and verified operation system

Accomplishments

- Created AADL model of vehicle hardware & software architecture
- Identified system-level requirements to be verified based on input from Red Team evaluations
- Developed Resolute analysis tool for capturing and evaluating assurance case arguments linked to AADL model
- Developed example assurance cases for two security requirements
- Developed synthesis tool for auto-generation of configuration data and glue code for OS and platform hardware

Open source tools available at github.com/smaccm

Building the Assurance Case throughout the Life Cycle



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Architecture-centric Virtual System Integration & Incremental Life-cycle Assurance

Reduce risks

- Analyze system early and throughout life cycle
- Understand system wide impact
- Validate assumptions across system

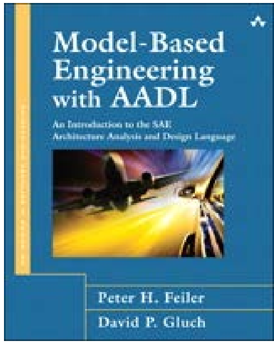
Increase confidence

- Validate models to complement integration testing
- Validate model assumptions in operational system
- Evolve system models in increasing fidelity

Reduce cost

- Fewer system integration problems
- Incremental evidence through compositional verification
- Fewer verification steps through generation from single source and verified models

References



AADL Website www.aadl.info and AADL Wiki www.aadl.info/wiki

Blog entries and podcasts on AADL at www.sei.cmu.edu

AADL Book in SEI Series of Addison-Wesley
http://www.informit.com/store/product.aspx?isbn=0321888944

On AADL and Model-based Engineering

http://www.sei.cmu.edu/library/assets/ResearchandTechnology_AADLandMBE.pdf

On an architecture-centric virtual integration practice and SAVI

http://www.sei.cmu.edu/architecture/research/model-based-engineering/virtual_system_integration.cfm

On an a four pillar improvement strategy for software system verification and qualification

http://blog.sei.cmu.edu/post.cfm/improving-safety-critical-systems-with-a-reliability-validation-improvement-framework

Webinars on system verification https://www.csiac.org/event/architecture-centric-virtual-integration-strategy-safety-critical-system-verification and on architecture trade studies with AADL https://www.webcaster4.com/Webcast/Page/139/5357

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